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Time-resolved characterization of secondary particle formation from a gasoline passenger car

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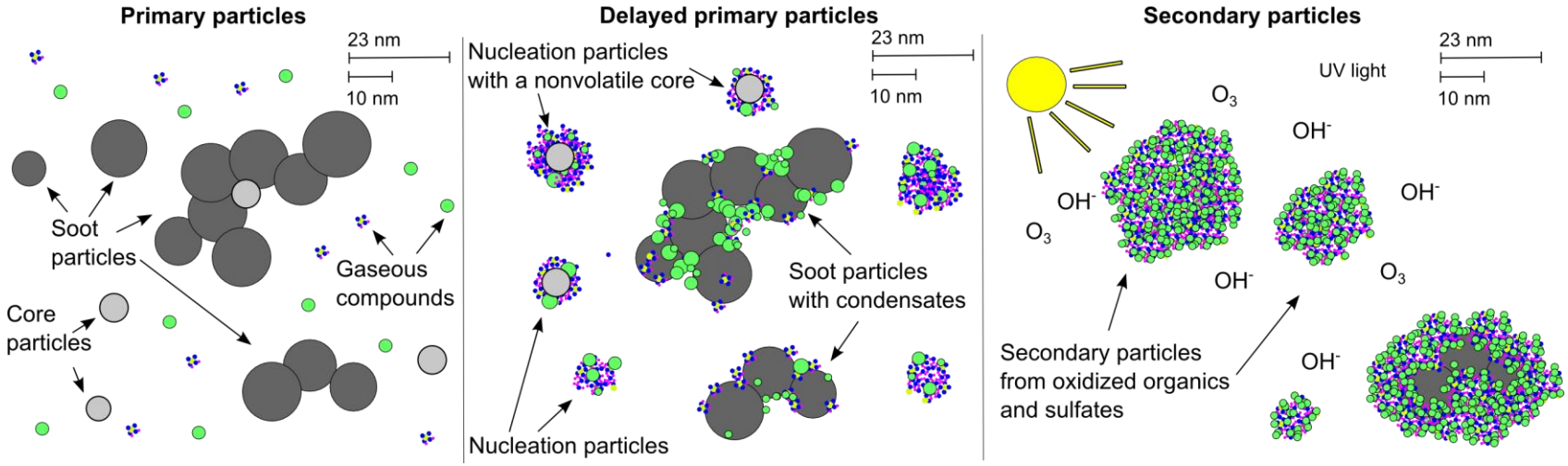
Contents

- Types of exhaust-related particles
- PAM chamber
- Experimental
- Results
  - Size distributions
  - Chemical composition
  - Effect of ethanol content
- Summary

Types of exhaust related particles



In hot exhaust

Directly after emission to the atmosphere

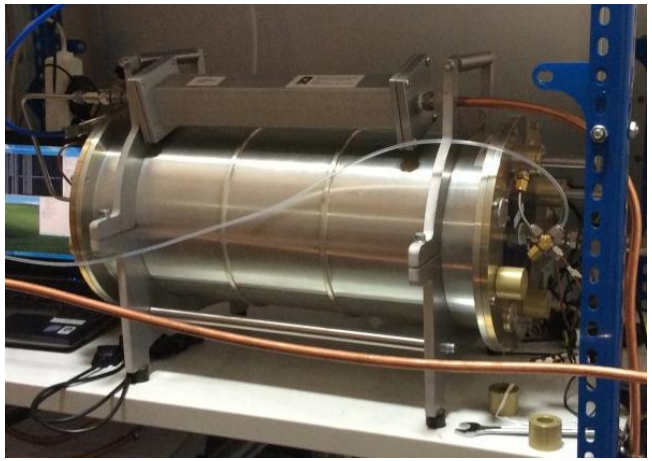
After oxidation processes in the atmosphere

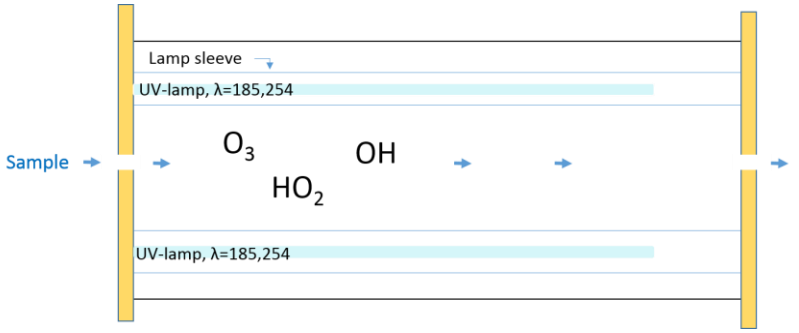
Time scale

Seconds | Seconds to minutes | Hours to days

Potential aerosol mass (PAM) chamber

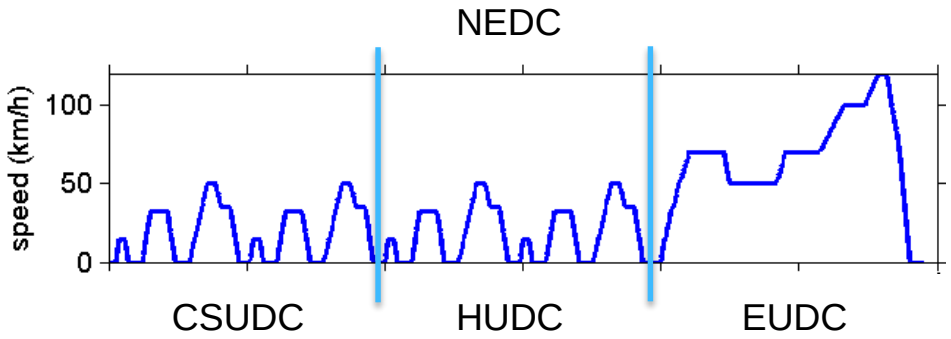
- Flow through chamber (Kang et al. 2007, Kang et al. 2011)
- High oxidant concentrations of O_3, OH, HO_2 and UV lights used in chamber are shown to simulate SOA formation in the atmosphere
- Flow 4-10 l/min
- Represents 2–20 days of atmospheric oxidation
- Not laminar, continuously mixed flow





Experimental

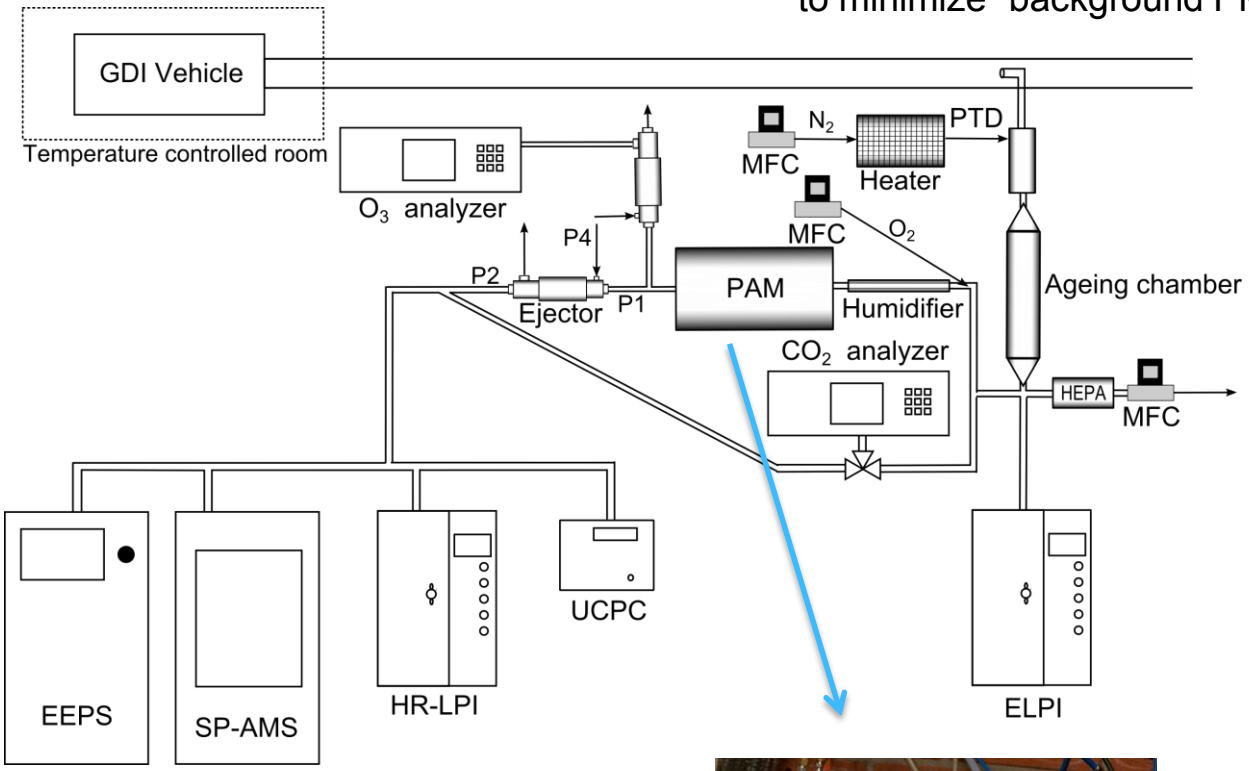
- Gasoline passenger car, model year 2011
- Odometer reading 48 700 km
- 1.4 l turbo-charged flex-fuel GDI engine
- 7 gear dual clutch automatic transmission
- Emission level Euro 5 with a three-way catalytic converter
- Test fuels comprised of
  - Regular commercial E10 fuel (max 10% ethanol)
  - Commercial E85 fuel (85% ethanol)
- The driving cycle used in the study was New European Driving Cycle (NEDC) on a chassis dynamometer in a climatic test cell at +23 °C.

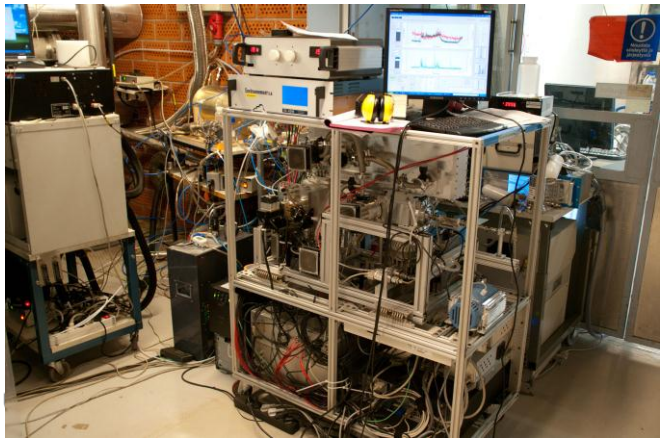


CSUDC = cold start urban driving cycle
HUDC = hot urban driving cycle
EUDC = extra-urban driving cycle

Sampling setup

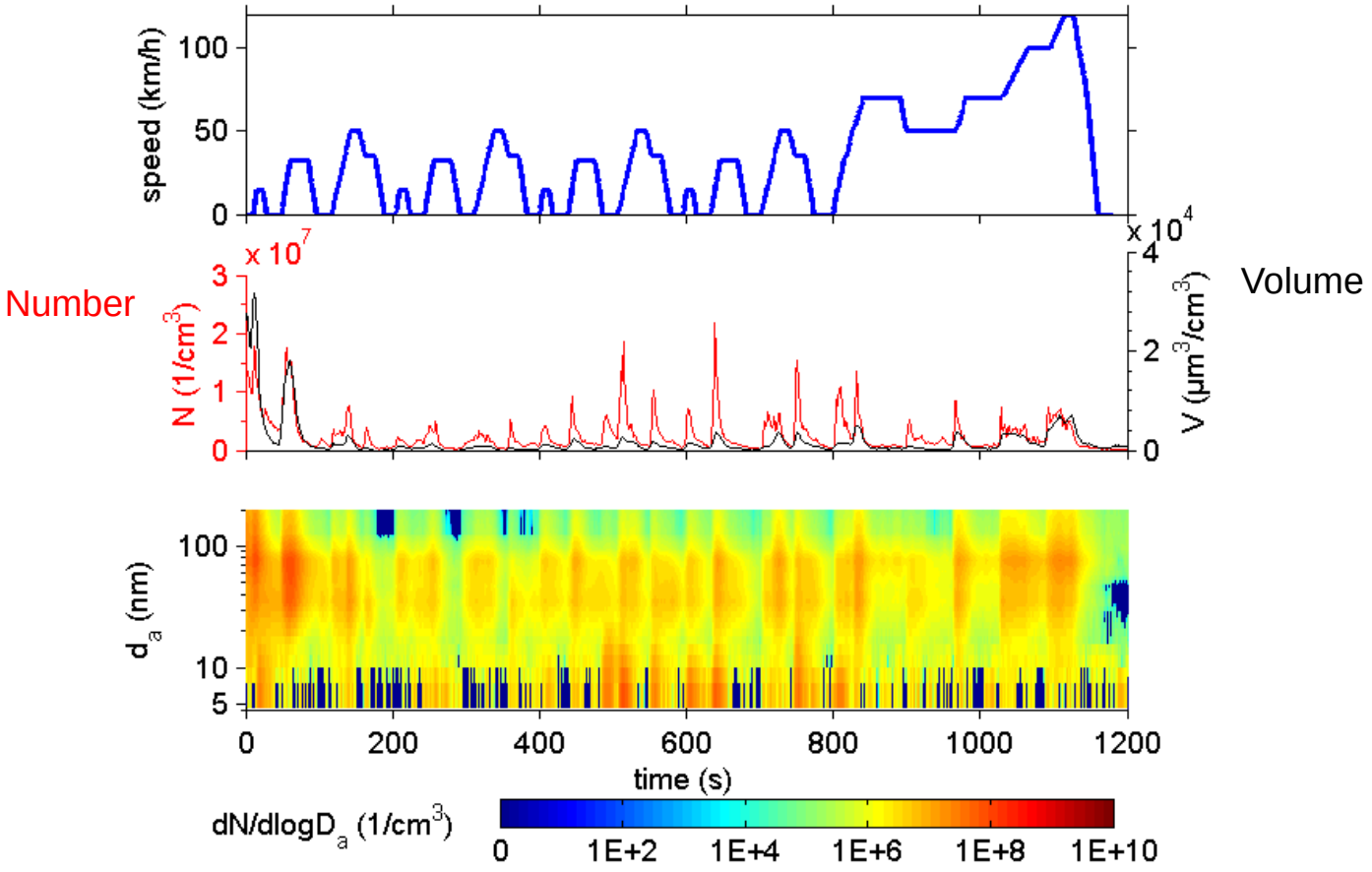
Dilutions with pure N_2 and O_2 to minimize ”background PM”





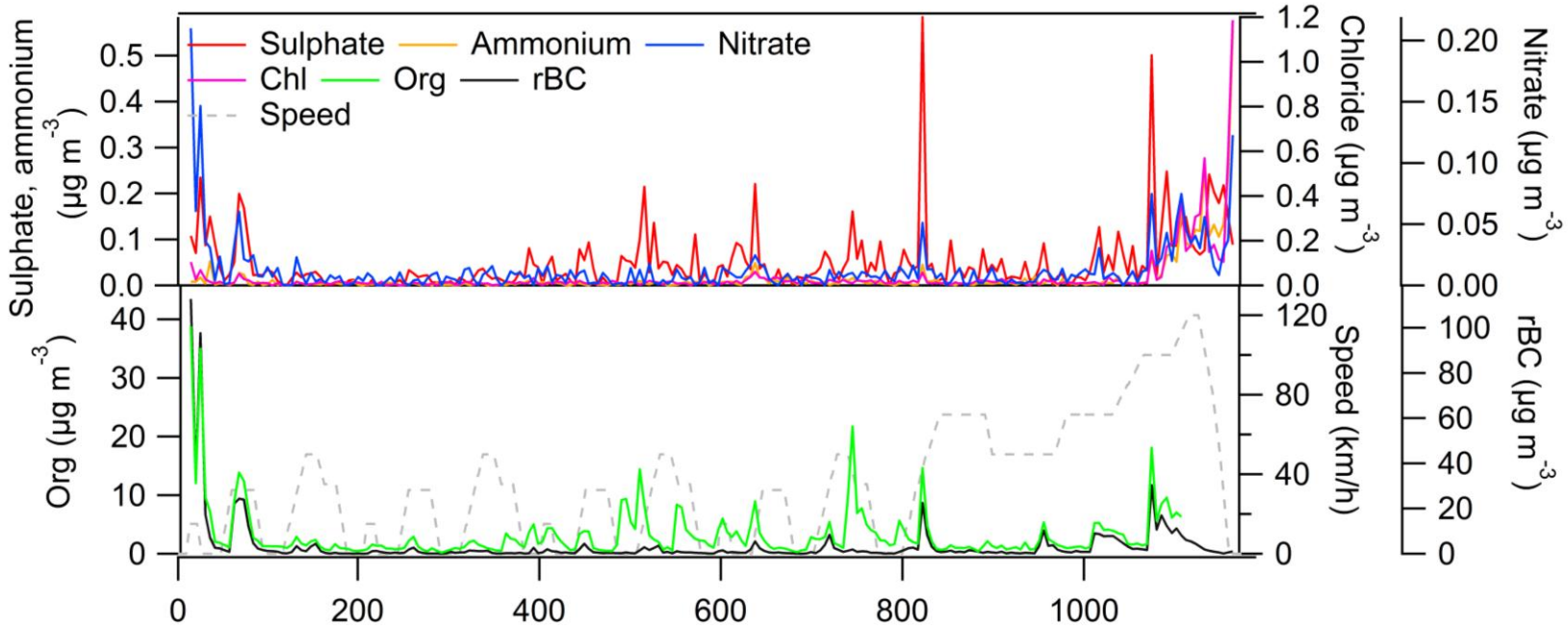
Here flow of 9.75 l/min in the PAM, mean residence time ~84 s (results corrected by delay)

Emission profile, ”delayed primary” particles over the NEDC



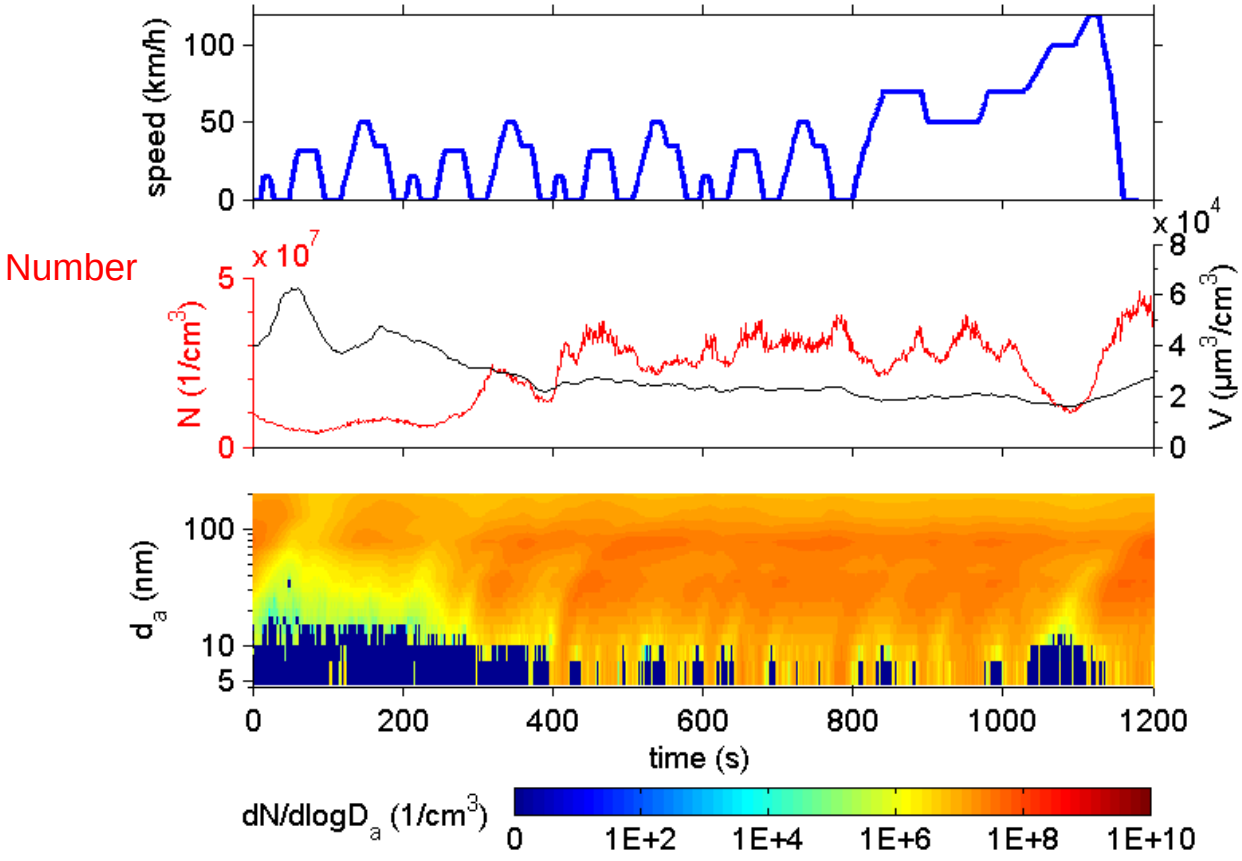
(Karjalainen et al. 2015)

Chemical composition, ”delayed primary” particles over the NEDC



(Karjalainen et al. 2015)

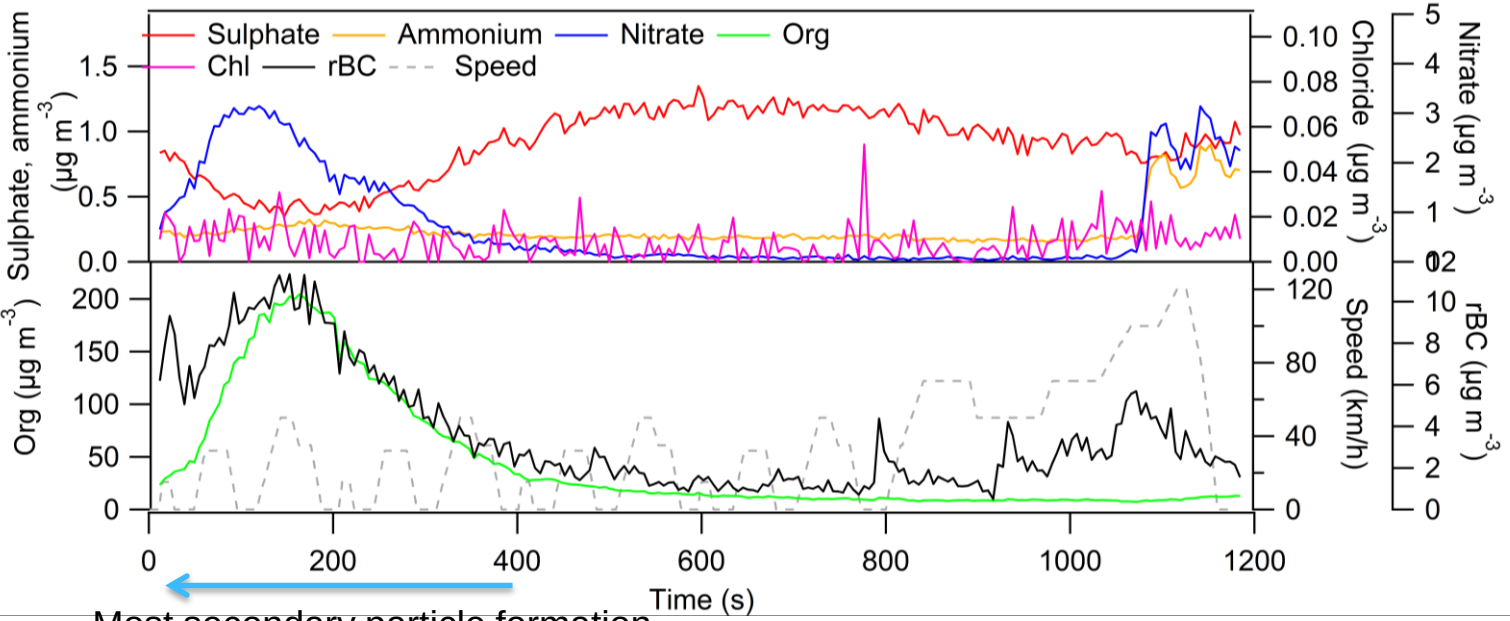
Emission profile, ”secondary” particles formed over the NEDC



(Karjalainen et al. 2015)

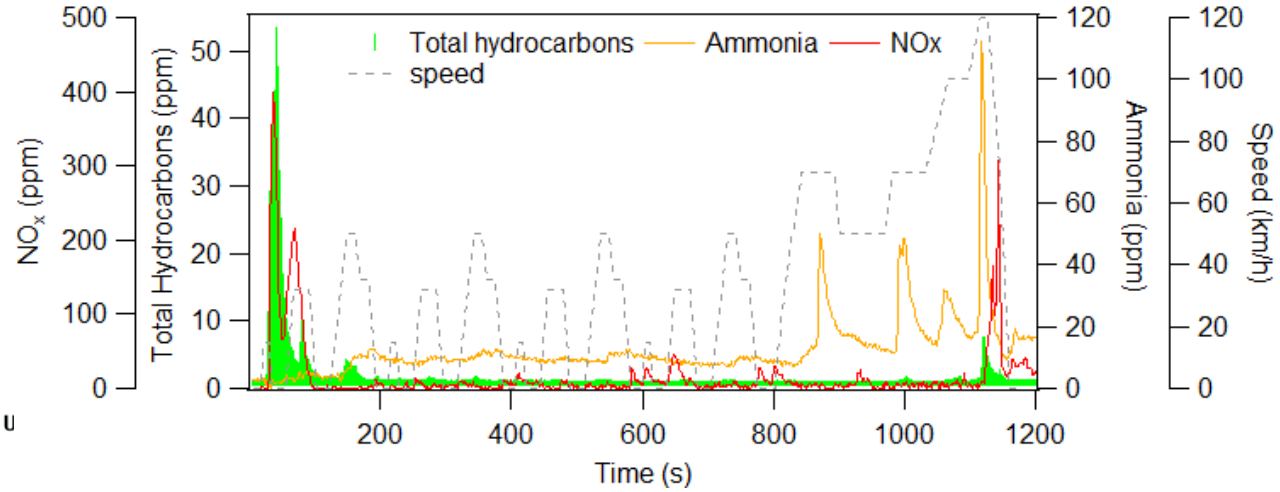
Chemical composition, ”secondary” particles over the NEDC

AMS data



Most secondary particle formation after the cold start, mostly organics

Gaseous emissions



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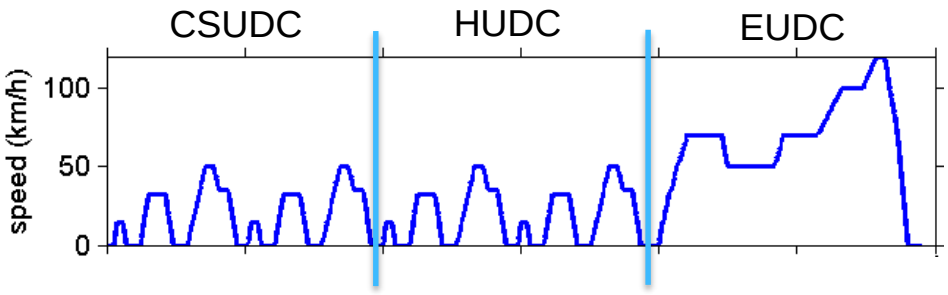
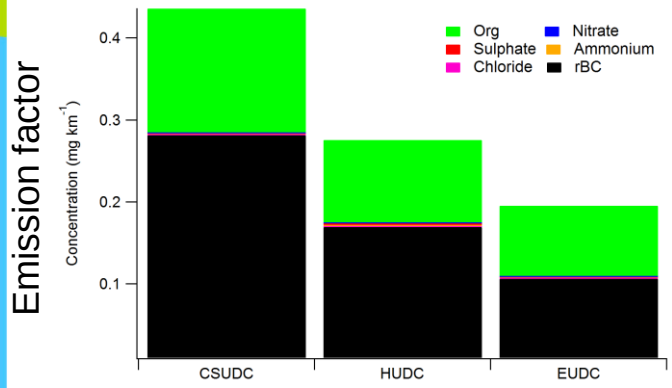
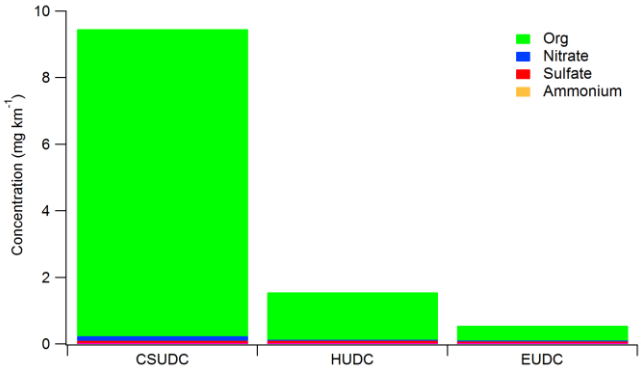
Chemical composition of particles during sub-cycles of NEDC

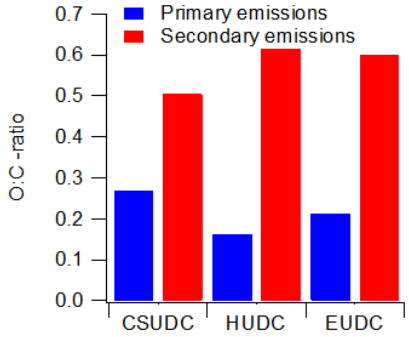


Delayed primary PM



Secondary PM

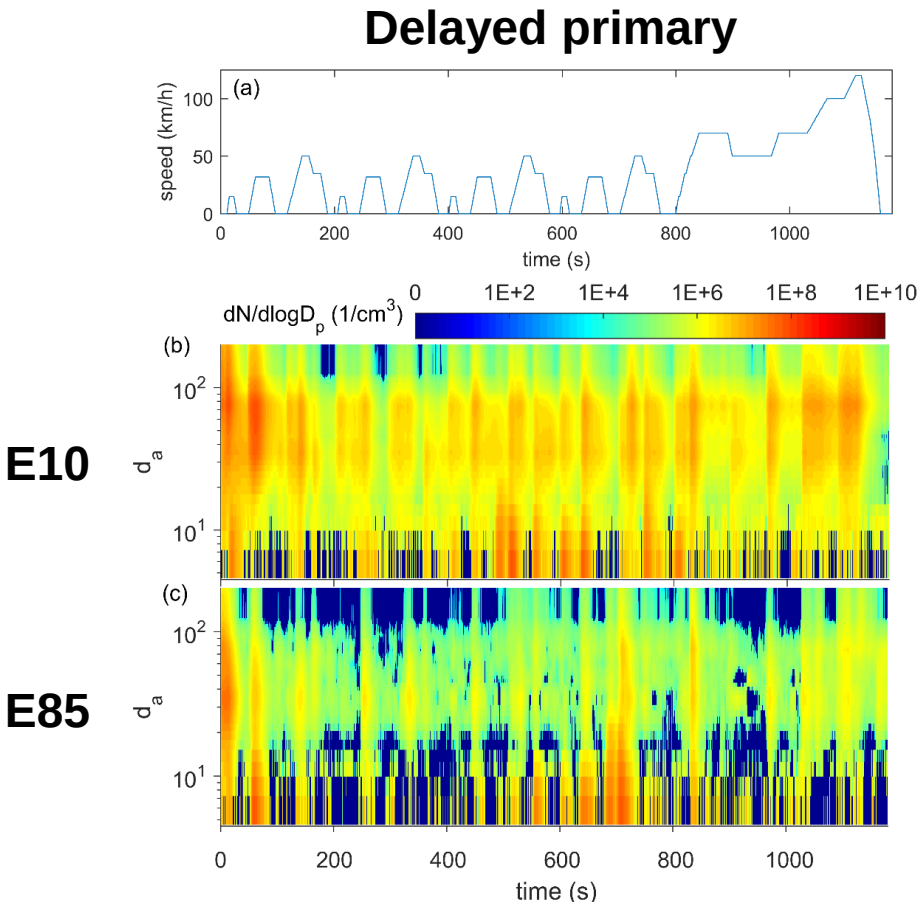




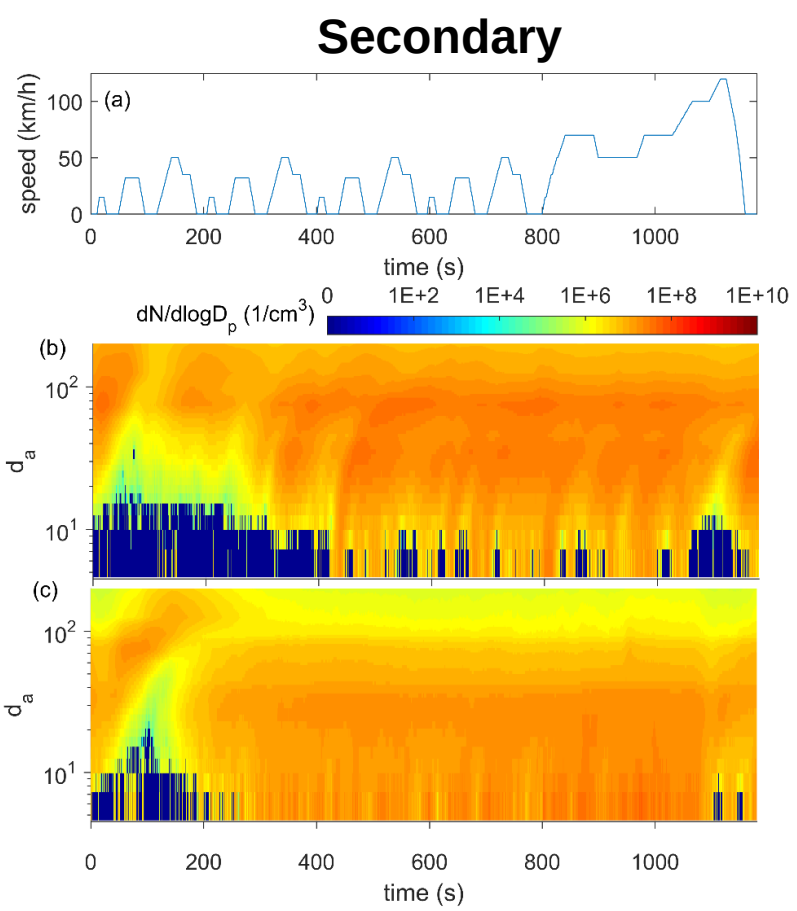
Secondary PM overall 13 times higher than delayed primary PM for the NEDC

(Karjalainen et al. 2015)

Size distributions with different ethanol contents



Less soot mode particles for E85

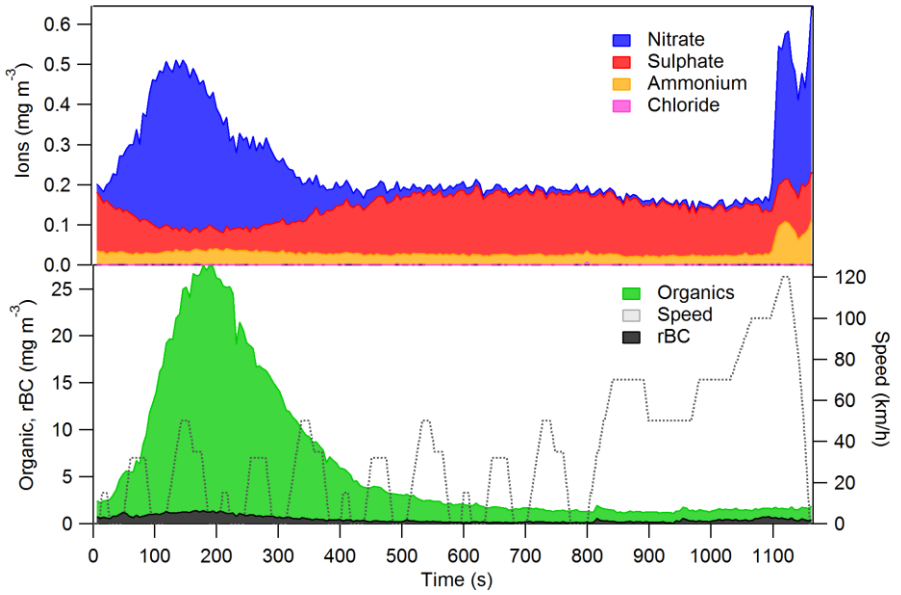


Mean particle size overall smaller for E85

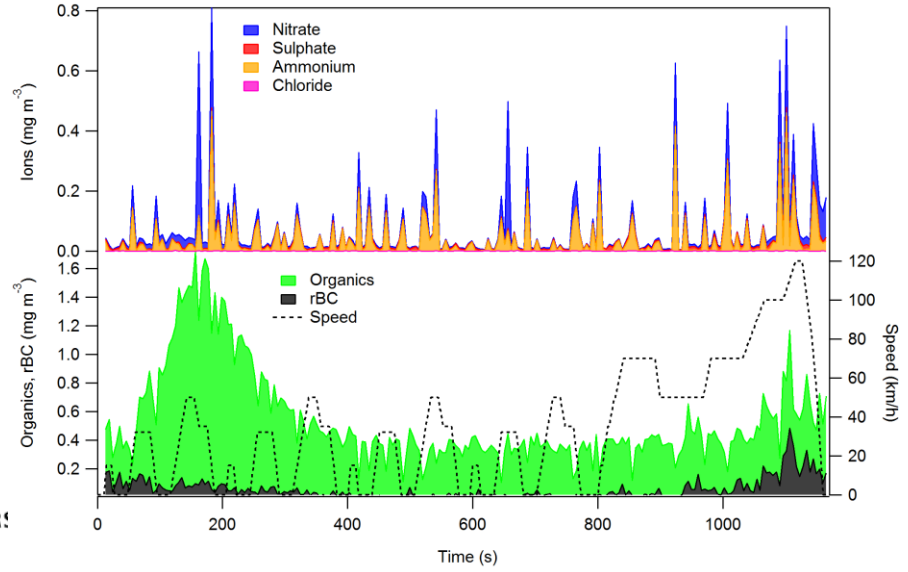
(Timonen et al. 2016)

Chemical composition, effects of ethanol on secondary PM

E10



E85



Large reduction in organics when increasing the ethanol content

E.g. peak in organics 26 µg/m^3 vs. 1.6 µg/m^3

Summary

- In mass terms, the amount of secondary particles was 13 times higher than the amount of delayed primary particles for E10
- The formation, composition, number, and mass of secondary particles was significantly affected by driving patterns and engine conditions
- The highest gaseous and particulate emissions were observed at the beginning of the test cycle when the performance of the engine and catalyst were below optimal
- The key parameter for secondary particle formation was the amount of gaseous hydrocarbons in primary emissions; however, also the primary particle population had an influence
- Increase in ethanol content reduced the secondary aerosol formation potential

Acknowledgements

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